Optimal Monetary Policy, Exchange Rate Misalignments and Incomplete Financial Markets*

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Abstract

Recent literature on monetary policy in open economies shows that, when international financial trade is restricted to a single non-contingent bond, there are significant internal and external trade-offs that prevent optimal policy from simultaneously closing all welfare gaps. This implies that optimal policy deviates from inflation targeting in order to offset real exchange rate misalignments. These simple models are, however, not good representations of modern financial markets. This paper therefore develops a more general and realistic two-country model of incomplete markets, where, in the presence of a wide range of stochastic shocks, there is international trade in nominal bonds and equities. The analysis shows that, as in the recent literature, optimal policy deviates from inflation targeting in order to offset exchange rate misalignments, but the welfare benefits of optimal policy relative to inflation targeting are quantitatively smaller than found in simpler models of financial incompleteness. It is nevertheless found that optimal policy implies quantitatively significant stabilisation of the real exchange rate gap and trade balance gap compared to inflation targeting.

Keywords: Optimal monetary policy, Financial market structure, Country Portfolios

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1 Introduction

To what extent should the design of monetary policy rules explicitly account for open economy factors such as current account imbalances or exchange rate misalignments? The early literature on optimal monetary policy in open economies gives the clear answer that open economy factors need have no explicit role in the design of monetary policy rules. For instance, the work of Clarida *et al* (2002), Gali and Monacelli (2005) and Benigno and Benigno (2003) shows that monetary policy should focus on targeting the rate of inflation of producer prices. These authors demonstrate that a policy of inflation targeting is sufficient to close all internal and external welfare gaps. So, for instance a policy of inflation targeting would imply a rise in the policy interest rate in response to a negative TFP shock and thus would close the gap between actual and potential output *and* also close the gap between the actual and welfare optimal real exchange rate and trade balance. There is therefore no trade-off between internal and external policy objectives. This early literature is in effect a direct extension to an open economy setting of the basic closed economy results of Woodford (2003) and Benigno and Woodford (2005). The only difference between the closed and open economy results is in the choice of price index for the inflation target - consumer prices for a closed economy and producer prices for an open economy.

This early open economy literature, however, focused on models where international financial markets are complete. Households can therefore fully hedge against country specific income shocks. More recent literature has begun to analyse monetary policy in open economy models where financial markets are incomplete. For instance, Corsetti *et al* (2010, 2011) analyse monetary policy in a context where international financial trade is absent or is restricted to a single non-contingent bond. They show that, in contrast to the previous literature, when international financial markets are incomplete there are significant internal and external trade-offs that prevent optimal policy from simultaneously closing all welfare relevant gaps.[1]

The basic intuition for the Corsetti *et al* (2010, 2011) results is simple to explain. A policy of producer price inflation targeting reproduces the flexible price outcome and

[1] Corsetti *et al* (2010, 2011) focus on optimal monetary policy in a symmetric two-country world. Benigno (2009) analyses an asymmetric world with incomplete financial markets and shows how optimal monetary policy differs between net-debtor and net-creditor countries. De Paoli (2010) analyses monetary policy for a small open economy and shows how optimal policy depends on the degree of financial integration.

therefore eliminates the welfare costs associated with staggered price setting. But the flexible price equilibrium is not fully optimal because international financial markets are imperfect and thus cross-country income risks are not optimally shared. A corollary of this is that the real exchange rate and trade balance will deviate from their first best outcomes. Corsetti *et al* (2010, 2011) show that optimal policy deviates from inflation targeting and takes account of external welfare gaps and acts to offset "exchange rate misalignments." They argue that external factors are particularly important in two cases. The first is when the elasticity of substitution between goods produced in different countries (i.e. the trade elasticity) is low. The second is when firms adopt local currency pricing (i.e. they set prices in the currency of the buyer).

The results in Corsetti *et al* (2010, 2011) clearly point to a potentially important deviation from the standard policy prescription of inflation targeting. There is however a significant limitation to Corsetti *et al*'s work. In Corsetti *et al* (2010) the analysis of imperfect international financial markets is restricted to a model with financial autarky, while in Corsetti *et al* (2011) the analysis of imperfect financial markets is represented by a single bond economy. These structures provide important insights into the implications of imperfect financial trade but they are obviously not a good representation of modern international financial markets.

The main objective of the current paper is to analyse more general models of imperfect international financial trade than those considered in Corsetti *et al* (2010, 2011). Our model is more general in a number of dimensions. Firstly, we examine a more general financial market structure where agents can trade in both equities and bonds. Secondly, we allow for more sources of stochastic shocks. And thirdly, in an extended version of the model, we incorporate variable real capital. By allowing for trade in a wider range of financial assets we provide more scope for hedging than in the Corsetti *et al* (2010, 2011) structure. By including more stochastic shocks we ensure that, despite the presence of more assets, financial markets are still not complete. Our model is therefore a more realistic framework for analysing the implications of imperfect financial markets for the design of optimal monetary policy rules. Our objective is to test whether the Corsetti *et al* (2010, 2011) results continue to hold in this more realistic structure and, if they do, what is the quantitative significance of financial market incompleteness in terms of departures from inflation stabilisation.

Because our model allows for international trade in nominal bonds and equities it is necessary to compute equilibrium gross portfolios. The size and composition of these portfolios will depend on the structure and stochastic environment of the model, including the properties of the monetary rule. There is therefore an interaction between policy choice and portfolio choice. Equilibrium portfolios are computed using techniques developed in recent literature (see Devereux and Sutherland (2010, 2011a) and Tille and van Wincoop (2010)). The combining of these techniques with the analysis of optimal policy is an important innovation of this paper.[2]

After describing our model our analysis focuses on a comparison between optimal policy and a policy of strict (producer price) inflation targeting. This comparison allows us to judge the extent to which optimal policy deviates from an internal objective (i.e. inflation stability) in order to achieve open economy objectives such as correcting real exchange rate misalignments. Our results show that the welfare gain of optimal policy relative to strict inflation targeting is quite small. This is true for a wide range of parameter values (including the cases emphasised by Corsetti *et al* (2010, 2011)). It therefore appears that the extra hedging possibilities offered by the wider range of assets incorporated in our model tends to reduce the trade-off between internal and external policy objectives that is highlighted by Corsetti *et al* (2010, 2011). However, our results show that, despite the small welfare gains generated by optimal policy, it continues to be the case that optimal policy tends to reduce the volatility of the real exchange rate and the trade balance (as measured against their first-best values). Thus optimal policy does tend to deviate from strict inflation targeting in order to correct measures of external misalignment.

The paper proceeds as follows. The model is presented in Section 2. Our definition of welfare and the characterisation of monetary policy is described in Section 3 and our methodology for deriving optimal policy rules in the presence of endogenous portfolio choice is described in Section 4. The main results of the paper are presented in Section 5 and the results from an extended version of the model are described in Section 6. Section 7 concludes the paper.

[2] Devereux and Sutherland (2008) consider a simple case where optimal monetary policy can be analysed alongside endogenous portfolio choice. However, in that case asset trade is restricted to two nominal bonds and only a limited range of exogenous shocks is considered. They show that, in these special circumstances, strict inflation targeting reproduces the full risk sharing outcome, so there is no trade-off between internal and external policy objectives.

2 The Model

We analyse a model of two countries with multiple sources of shocks. The model shares many of the same basic features of the closed economy models developed by Christiano *et al* (2005) and Smets and Wouters (2003). It is based on the open economy model developed in Devereux *et al* (2014).

Households consume a basket of home and foreign produced final goods. Final goods are produced by monopolistically competitive firms which use intermediate goods as their only input. Final goods prices are subject to Calvo-style contracts. Intermediate goods are produced by perfectly competitive firms using labour and real capital as inputs. Intermediate goods prices are perfectly flexible. In the benchmark version of the model the capital stock is fixed. In an extended version of the model we allow for variable capital stocks which are subject to adjustment costs. Households supply homogeneous labour to perfectly competitive firms producing intermediate goods. All profits from firms in the intermediate and final goods sectors are paid to holders of equity shares.

We allow for international trade in equities and nominal bonds. Home and foreign equities represent claims on aggregate firm profits of each country, and home and foreign nominal bonds are denominated in the currency of each country.

The following sections describe the home country in detail. The foreign country is identical. An asterisk indicates a foreign variable or a price in foreign currency.

2.1 Households

Household z in the home country maximizes a utility function of the form

$$U_t = E_t \sum_{i=0}^{\infty} \beta_i \left\{ \Psi_{t+i} \frac{C_{t+i}^{1-\rho}(z)}{1-\rho} - \Delta_{t+i} \frac{H_{t+i}^{1+\phi}(z)}{1+\phi} \right\} \tag{1}$$

where $\rho > 0$, $\phi > 0$, $C(z)$ is the consumption of household z, $H(z)$ is labour supply, β is the discount factor and Ψ_t and Δ_t are stochastic preference shocks which affect consumption and labour supply respectively. We assume $\Delta_t = \bar{\Delta} \exp(\hat{\Delta}_t)$ where $\hat{\Delta}_t = \eta_\Delta \hat{\Delta}_{t-1} + \varepsilon_{\Delta,t}$, $0 \leq \eta_\Delta < 1$ and $\varepsilon_{\Delta,t}$ is a zero-mean normally distributed i.i.d. shock with $Var[\varepsilon_\Delta] = \sigma_\Delta^2$ and $\Psi_t = \bar{\Psi} \exp(\hat{\Psi}_t)$ where $\hat{\Psi}_t = \eta_\Psi \hat{\Psi}_{t-1} + \varepsilon_{\Psi,t}$, $0 \leq \eta_\Psi < 1$ and $\varepsilon_{\Psi,t}$ is a zero-mean normally distributed i.i.d. shock with $Var[\varepsilon_\Psi] = \sigma_\Psi^2$.

Taste shocks in the form of Ψ_t are emphasised by Corsetti *et al* (2010, 2011) because they create a strong role for current account dynamics and thus potentially create a strong welfare trade-off for monetary policy when financial markets are incomplete.

The discount factor, β_i, is endogenous and is determined as follows

$$\beta_{i+1} = \bar{\beta}\beta_i \left(\frac{C_{A,i}}{\bar{C}_A} \right)^{-\eta}, \ \beta_0 = 1 \tag{2}$$

where $0 < \eta < \rho$, $0 < \bar{\beta} < 1$, C_A is aggregate home consumption and $\bar{C}_A$ is a constant.[3]

We define C_t to be a consumption basket which aggregates home and foreign goods according to:

$$C_t = \left[\gamma^{\frac{1}{\theta}} C_{H,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{F,t}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{3}$$

where C_H and C_F are baskets of individual home and foreign produced goods. The elasticity of substitution across individual goods within these baskets is $\lambda > 1$. The parameter θ in (3) is the elasticity of substitution between home and foreign goods. The parameter γ measures the importance of consumption of the home good in preferences. For $\gamma > 1/2$, we have 'home bias' in preferences.

The price index associated with the consumption basket C_t is

$$P_t = \left[\gamma P_{H,H,t}^{1-\theta} + (1-\gamma) P_{F,H,t}^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{4}$$

where $P_{H,H}$ is the price index of home goods for home consumers and $P_{F,H}$ is the price index of foreign goods for home consumers. The corresponding price indices for foreign consumers are $P_{H,F}$ and $P_{F,F}$.

The flow budget constraint of the home country household is

$$P_t C_t + P_t F_t = w_t H_t + P_t \Pi_t - P_t T_{D,t} + P_t \sum_{k=1}^{N} \alpha_{k,t-1} r_{kt} \tag{5}$$

where F_t denotes home country net external assets in terms of the home consumption basket, w_t is the home nominal wage, Π_t is profits of all home firms and $T_{D,t}$ is lump-sum taxes imposed on households. The final term represents the total return on the home country portfolio where $\alpha_{k,t-1}$ represents the real *external* holdings of asset k (defined in terms of the home consumption basket) purchased at the end of period $t-1$ and $r_{k,t}$ represents the gross real return on asset k. In our analysis, we allow for trade in $N = 4$ assets; home and foreign equity and home and foreign nominal bonds. Note that $F_t = \sum_{k=1}^{N} \alpha_{k,t}$.

Nominal bonds are assumed to be perpetuities, so for instance, home nominal bonds represent a claim on a unit of home currency in each period into the infinite future. The

[3] Following Schmitt-Grohe and Uribe (2003), β_i is assumed to be taken as exogenous by individual decision makers. The impact of individual consumption on the discount factor is therefore not internalized.

real price of the home bond is denoted $Z_{B,t}$. The gross real rate of return on a home bond is thus $r_{Bt+1} = (1/P_{t+1} + Z_{B,t+1})/Z_{B,t}$. For the foreign nominal bond, the real return on foreign bonds, in terms of home consumption, is $r_{B^*t+1} = (Q_{t+1}/Q_t)(1/P^*_{t+1} + Z^*_{B,t+1})/Z^*_{B,t}$, where $Q_t = S_t P^*_t/P_t$ is the real exchange rate (where S is the price of the foreign currency in terms of the home currency).

Home equities represent a claim on aggregate profits of all firms in the home final and intermediate sectors. The real payoff to a unit of the home equity purchased in period t is defined to be $\Pi_{t+1} + Z_{E,t+1}$, where $Z_{E,t+1}$ is the real price of home equity and Π_{t+1} is real aggregate profits. Thus the gross real rate of return on the home equity is $r_{E,t+1} = (\Pi_{t+1} + Z_{E,t+1})/Z_{E,t}$.

2.2 Firms

Within each country firms are divided between final and intermediate sectors. Intermediate goods firms use labour and real capital. There is a unit mass of firms in both the final and intermediate levels.

2.2.1 Final goods

Each firm in the final goods sector produces a single differentiated product. Sticky prices are modelled in the form of Calvo (1983) style contracts with a probability of re-setting price given by $1 - \kappa$. We consider both producer currency pricing (PCP) and local currency pricing (LCP).

If firms use the discount factor Ω_t to evaluate future profits, then, in the PCP case, firm z chooses its prices for home and foreign buyers, $p_{H,H,t}(z)$ and $p_{H,F,t}(z)$, in home currency to maximize

$$E_t \sum_{i=0}^{\infty} \Omega_{t+i} \kappa^i \left\{ y_{H,H,t+i}(z) \frac{[p_{H,H,t}(z) - q_{t+i}]}{P_{t+i}} + y_{H,F,t+i}(z) \frac{[p_{H,F,t}(z) - q_{t+i}]}{P_{t+i}} \right\} \tag{6}$$

where $y_{H,H}(z)$ is the demand for home good z from home buyers and $y_{H,F}(z)$ is the demand for home good z from foreign buyers and q is the price of the intermediate good.

In the LCP case firm z chooses $p_{H,H,t}(z)$ in home currency and $p^*_{H,F,t}(z)$ in foreign currency to maximize (6) where $p_{H,F,t}(z)$ is replaced by $p^*_{H,F,t}(z)S_{t+i}$ where S is the nominal exchange rate (defined as the foreign currency in terms of the home currency).

Monopoly power in the final goods sector implies that final goods prices are subject to a mark-up given by $\upsilon_t = \lambda_t/(\lambda_t - 1)$. The mark-up is assumed to be subject to stochastic shocks such that $v_t = \bar{v}\exp(\hat{v}_t)$ where $\hat{v}_t = \eta_v \hat{v}_{t-1} + \varepsilon_{v,t}$, $0 \leq \eta_v < 1$ and $\varepsilon_{v,t}$ is a zero-mean normally distributed i.i.d. shock with $Var[\varepsilon_v] = \sigma_v^2$.

2.2.2 Intermediate goods

The representative firm in the intermediate goods sector combines labour, L, and capital, K, to produce output Y using a standard Cobb-Douglas technology, $Y_t = A_t K_{t-1}^{1-\mu} L_t^{\mu}$.

We assume that total factor productivity, A_t, is determined as follows

$$A_t = U_t - V_t$$

where

$$U_t = \eta_u U_{t-1} + \varepsilon_{v,t} + \varepsilon_{u,t} \qquad\qquad V_t = \eta_v V_{t-1} + \varepsilon_{v,t}$$

where $\eta_u > \eta_v$ and $\varepsilon_{v,t}$ and $\varepsilon_{u,t}$ are zero mean normally distributed i.i.d. shocks. This structure captures the concept of "news shocks" as in Beaudry and Portier (2006). News shocks are emphasised by Corsetti *et al* (2010, 2011) because news shocks create a strong role for current account dynamics and therefore a potentially strong welfare trade-off between internal and external policy objectives when financial markets are incomplete.

In the benchmark version of the mode we assume that the stock of real capital is fixed at $\bar{K}$.

The representative firm chooses L_t to maximize the real discounted value of dividends, given by

$$E_t \sum_{i=0}^{\infty} \Omega_{t+i} \left[\frac{q_{t+i}}{P_{t+i}} Y_{t+i} - \frac{w_{t+i}}{P_{t+i}} L_{t+i} \right]$$

subject to the production function where q is the price of intermediate goods. Ω_t is assumed to be the stochastic discount factor of shareholders of the firm.

2.3 Government

Total government expenditure is assumed to be exogenous and subject to stochastic shocks. In particular we assume that $G_t = \bar{G}\exp(\hat{G}_t)$ is government spending where $\hat{G}_t = \eta_G \hat{G}_{t-1} + \varepsilon_{G,t}$, $0 \leq \eta_G < 1$ and $\varepsilon_{G,t}$ is a zero-mean normally distributed i.i.d. shock with $Var[\varepsilon_G] = \sigma_G^2$.

All government spending is financed via lump sum taxes on households, T_D, and firms, T_C. The budget constraint is $P_{G,t}G_t = P_t T_{D,t} + P_t T_{C,t}$ where it is assumed that $P_t T_D = (1-\varrho) P_{G,t} G$ and $P_t T_C = \varrho P_{G,t} G$ where ϱ is a fixed parameter which determines the share of profit taxes in the overall tax take. $P_{G,t}$ is the price index of government purchased goods. It is assumed that government spending is on domestically produced goods so $P_{G,t} = P_{H,H,t}$.

As with taste and news shocks, transitory government spending shocks of the type assumed here create a potentially strong role for current account dynamics and therefore a potentially strong welfare trade-off between internal and external policy objectives when financial markets are incomplete.

2.4 Equilibrium

Home demand for home final goods is

$$D_{H,t} = \gamma \left(\frac{P_{H,H,t}}{P_t} \right)^{-\theta} C_t \tag{7}$$

Each home country firm in the final goods sector faces demand for its good from the home and foreign countries. Equilibrium in the market for good z in the home country final goods sector implies $y_t(z) = y_{H,H,t}(z) + y_{H,F,t}(z)$ where

$$y_{H,H,t}(z) = \left(\frac{p_{H,H,t}(z)}{P_{H,H,t}} \right)^{-\lambda} [D_{H,t} + G_t] \qquad y_{H,F,t}(z) = \left(\frac{p^*_{H,F,t}(z)}{P^*_{H,F,t}} \right)^{-\lambda} D^*_{H,t} \tag{8}$$

where $D^*_{H,t}$ is the foreign demand for home goods (defined analogously to (7)).

Aggregate GDP for the home economy is given by

$$Y_t = \frac{P_{H,H,t}}{P_{Y,t}} [D_{H,t} + G_t] + \frac{S_t P^*_{H,F,t}}{P_{Y,t}} D^*_{H,t}$$

where $P_{Y,t}$ is the GDP deflator, which we define as follows

$$P_{Y,t} = [(1-g)\gamma + g] P_{H,H,t} + (1-g)(1-\gamma) S_t P^*_{H,F,t}$$

where g is the steady-state share of government spending in GDP.

Equilibrium in the labour market implies $L_t = H_t$.

Total after-tax dividends aggregated across all intermediate and final goods firms are given by

$$\Pi_t = \frac{P_{Y,t}}{P_t} Y_t - \frac{w_t}{P_t} L_t - T_{C,t}$$

Home equities represent claims on Π_t (into the infinite future).

It is useful to define the terms of trade as follows

$$\tau = \frac{S_t P^*_{H,F,t}}{P_{F,H,t}}$$

3 Monetary Policy and Welfare

The particular welfare measure on which we focus is the unconditional expectation of aggregate period utility. For the home economy this is defined as follows

$$U = E\left\{\Psi\frac{C^{1-\rho}}{1-\rho} - \Delta\frac{H^{1+\phi}}{1+\phi}\right\} \tag{9}$$

where time subscripts are omitted to indicate that this is a measure of unconditional expectation. Damjanovic *et al* (2008) argue that unconditionally expected utility provides a useful alternative to Woodford's (2003) 'timeless perspective' when analysing optimal policy problems. For the purposes of this paper, unconditional expected utility provides a simple and convenient way to compute welfare in a context where portfolio allocation is endogenous. The next section provides a more detailed discussion of the complications that arise in the simultaneous computation of welfare and equilibrium portfolios.

In common with Corsetti *et al* (2010, 2011) and much of the previous literature we focus on co-operative policy in the sense that policy rules for each country are simultaneously chosen to maximise global welfare, i.e. the sum of the home and foreign welfare measures.

We model monetary policy in the form of a 'targeting rule'.[4] In general the optimal targeting rule is model dependent. Corsetti *et al* (2010, 2011) show that the optimal targeting rule for a model similar to ours includes measures of inflation and a number of welfare gaps. Because of the complicated interaction between policy and portfolio choice we do not derive the fully optimal policy rule for our model. Instead we use the form of the optimal rule derived by Corsetti *et al* (2010, 2011) as an approximation for optimal policy in our model.

For the home economy, the targeting rule derived by Corsetti *et al* (2010, 2011) has the following form

$$\begin{aligned}\delta_\pi(\hat{P}_{Y,t} - \hat{P}_{Y,t-1}) + (1-\delta_\pi)(\hat{P}_t - \hat{P}_{t-1}) + \delta_Y(Y_{G,t} - Y_{G,t-1}) \\ +\delta_\tau(\tau_{G,t} - \tau_{G,t-1}) + \delta_{\mathcal{D}}(\mathcal{D}_t - \mathcal{D}_{t-1}) + \delta_{\mathcal{L}}(\mathcal{L}_t - \mathcal{L}_{t-1}) = 0\end{aligned} \tag{10}$$

[4] As argued by Woodford (2003), a 'targeting rule' is a convenient way to capture the welfare trade-offs faced by policy makers. It allows policy to be specified in terms of an optimal equilibrium relationship between various welfare 'gaps'. Once policy is specified in this way there is no need explicitly to model policy in terms of the optimal setting of a policy instrument (such as the nominal interest rate). However, an implied optimal rule for the policy instrument can easily be derived once the optimal equilibrium has been derived.

where a hat over a variable represents its log deviation from the non-stochastic steady state and Y_G, τ_G, $\mathcal{D}$ and $\mathcal{L}$ are defined as follows

$$Y_G = \hat{Y} - \hat{Y}^{fb}$$

$$\tau_G = \hat{\tau} - \hat{\tau}^{fb}$$

$$\mathcal{D} = -\rho\left(\hat{C} - \hat{C}^{*}\right) + \hat{Q} - (\hat{\Psi} - \hat{\Psi}^{*})$$

$$\mathcal{L} = \hat{P}_{H,H} - \hat{S} - \hat{P}^{*}_{H,F}$$

where the superscript fb indicates the first best value of a variable. Thus Y_G is a measure of the output gap and τ_G is a measure of the terms of trade gap. The variables $\mathcal{D}$ and $\mathcal{L}$ also measure deviations from first best outcomes. As will be explained in more detail below, $\mathcal{D}$ is a measure of the deviation from full risk sharing and $\mathcal{L}$ is a measure of the deviation from the law of one price. There is an analogous targeting rule for the foreign economy.

The targeting rule in (10) contains six terms. The first two terms represent a weighted average of producer price (PPI) and consumer price (CPI) inflation. The central role of inflation stabilisation in optimal policy in New Keynesian models is a well-known consequence of staggered price setting. In essence, staggered price setting implies that inflation causes distortions in relative prices between goods. Inflation is thus (other things equal) welfare reducing. It is also well-known that, in the presence of PCP, the welfare-relevant measure of inflation is PPI inflation. This is captured by the first term in (10). Engel (2011) shows that, for certain parameter combinations, in the LCP case the welfare-relevant measure of inflation is CPI inflation. Corsetti *et al* (2010, 2011) show that, for general parameter combinations, in the LCP case the welfare-relevant measure of inflation is effectively a weighted average of PPI and CPI inflation. This general case is therefore captured by the first two terms in (10).

The third term in (10) measures the welfare-relevant output gap. Again the role of the output gap in optimal targeting rules in New Keynesian models is well-known and needs no further explanation.

The fourth term in the targeting rule measures the welfare-relevant terms-of-trade gap. As Corsetti *et al* (2010, 2011) explain in detail, in an open economy, because there are different baskets of goods produced in different countries, shocks may have distortionary effects on the relative price of these different baskets. These distortions are welfare reducing in the same way as the within-country price distortions generated by inflation are welfare reducing. The terms of trade gap therefore plays the same role in the monetary policy rule as the CPI and PPI inflation terms.

The fifth term in the targeting rule is referred to by Corsetti *et al* (2010, 2011) as a measure of "demand imbalances". It measures deviations from full risk sharing. This captures the welfare reducing effects of incomplete financial markets. To understand this term note that, if a complete set of financial instruments were available for international trade, equilibrium in financial markets would imply that the ratio of marginal utilities across countries would equal the relative price of consumption baskets, i.e.

$$\frac{\Psi_t^* C_t^{*-\rho}}{\Psi_t C_t^{-\rho}} = Q_t$$

or in terms of log-deviations

$$-(\hat{\Psi} - \hat{\Psi}^*) - \rho\left(\hat{C} - \hat{C}^*\right) + \hat{Q} = 0$$

This is the well-known risk sharing condition that is standard in open-economy models with complete financial markets. It is thus clear that $\mathcal{D}$ in (10) is a measure of deviations from full risk sharing. And it is clear that this term in the monetary policy rule captures the extent to which monetary policy is adjusted in order to achieve greater risk sharing.

The final term in the targeting rule captures the welfare reducing effects of deviations from the law of one price. Such deviations are a direct consequence of (and only arise from) local currency pricing. In a similar way to the price distortions caused by staggered pricing, deviations from the law of one price are a form of price distortion which potentially requires a monetary policy response.

The six terms in the policy rule capture a range of potential welfare trade-offs that feature in the optimal setting of monetary policy. Internal (i.e. with-in country) trade-offs are captured by the inflation terms and the output gap. External (i.e. open economy) trade-offs are captured by the terms of trade, demand imbalances and law-of-one-price terms in the policy rule. The object of the analysis presented below is to determine the optimal values of the coefficients of the policy rule and thus to determine the role of external versus internal trade-offs in the optimal setting of monetary policy.

Note that policy rule (10) contains CPI and PPI inflation targeting as special cases. CPI inflation targeting is given by $\delta_\pi = \delta_Y = \delta_\tau = \delta_\mathcal{D} = \delta_\mathcal{L} = 0$ and PPI inflation targeting is given by $\delta_\pi = 1$, $\delta_Y = \delta_\tau = \delta_\mathcal{D} = \delta_\mathcal{L} = 0$.

4 Model Solution, Country Portfolios and Policy Optimisation

Our objective in this paper is to analyse optimal monetary policy in the above specified model. The key distinguishing feature of the above model, that sets it apart from much of the existing literature on optimal monetary policy in open economies, is that it allows for international trade in multiple assets. Recently developed solution techniques (Devereux and Sutherland, 2011a) make it possible to solve for equilibrium portfolio allocation in models of this type and there is now an active literature applying these techniques to a range of positive questions. The purpose of our paper is to apply these techniques to the analysis of optimal monetary policy in the presence of endogenous portfolio choice.

Combining the analysis of optimal policy and endogenous portfolio choice presents some new technical challenges. These challenges arise because there is an interaction between policy choices and portfolio choice. Portfolio choices depend on the stochastic properties of income and the hedging properties of available assets. Monetary policy affects the stochastic behaviour of income and the hedging properties of assets and therefore affects optimal portfolio choice. In turn, the equilibrium portfolio affects consumption and labour supply choices and thus affects macroeconomic outcomes and welfare. Thus, in addition to the standard routes via which policy affects the macro economy, the optimal choice of monetary policy must take account of the welfare effects of policy that occur via the effects of policy on portfolio allocation.

Our solution approach follows the recent portfolio literature based on Devereux and Sutherland (2011a) in computing equilibrium portfolios using a second order approximation to the portfolio selection equations for the home and foreign country in conjunction with a first order approximation to the home and foreign budget constraints and the vector of excess returns. The innovation in this paper is to combine this portfolio solution approach with an analysis of optimal monetary policy.

As already explained, we model monetary policy as targeting rule (10). We optimise the choice of coefficients in the targeting rule by means of a grid search algorithm. Each grid point represents a different setting of the coefficients of the targeting rule and for each grid point there is an equilibrium portfolio allocation and a corresponding general macroeconomic equilibrium and level of welfare. We use the Devereux and Sutherland portfolio solution approach to evaluate the equilibrium portfolio at each grid point. This equilibrium portfolio is then used to compute macroeconomic equilibrium and a second order approximation of welfare at each grid point.

To be specific, our policy optimisation problem involves a grid search across the five coefficients of the policy rule in (10), i.e. δ_π, δ_Y, δ_τ, $\delta_{\mathcal{D}}$ and $\delta_{\mathcal{L}}$, in order to identify the parameter combination which maximises the unconditional expectation of period welfare (as defined in (120)).[5]

It should be noted that this methodology does not compute fully optimal policy because fully optimal policy may involve more inertia than is embodied in the above specified targeting rule (as is shown in Corsetti *et al* (2010, 2011) in some cases). Our optimal rule is therefore the optimal rule within the restricted class of rules defined by (10). The focus on a non-inertial targeting rule is a convenient simplification given the extra complications and computational burden arising from the endogenous determination of equilibrium portfolios.

5 Comparison of Optimal Monetary Policy and Inflation Targeting

5.1 Benchmark parameter values

The benchmark parameter values used in the following analysis are listed in Table 1. Many of these parameter values are taken directly from Corsetti *et al* (2010, 2011). The values of λ (the elasticity of substitution between individual final goods) and μ (the Cobb-Douglas coefficient on labour in the production function of intermediate goods) are chosen to yield a steady state monopoly mark-up of 11% and share of capital in output of 0.33. The implied steady state share of dividends in GDP is approximately 0.15. The Calvo parameter for price setting, κ, is chosen to imply an average period between price changes of 4 quarters. The values of ϕ (inverse labour elasticity) and ρ (risk aversion) are consistent with the estimates of Smets and Wouters (2003, 2005, 2007). The steady state share of government spending in GDP, g, is set at 0.2 and the share of dividend taxes in total taxes, ϱ, is set at 0.15 (which is approximately the same as the assumed steady state share of dividends in total income). The parameters of the endogenous discount factor, $\bar{\beta}$ and η, are chosen to yield a steady state rate of return of approximately 4%.

[5] Given that the model is symmetric, the foreign country has a similarly defined targeting rule and the coefficients of that rule are assumed to be identical to the coefficients of the home rule, with appropriate changes of sign.

Table 1: Benchmark Parameter Values

Discount factor	$\bar{\beta} = 0.99$, $\eta = 0.005$
Elasticity of substitution: individual goods	$\lambda = 6$
Elasticity of labour supply	$1/\phi = 0.5$
Risk aversion	$\rho = 2$
Share of home goods in consumption basket	$\gamma = 0.875$
Elasticity of substitution: home and foreign goods	$\theta = 0.25$ - 6.00
Share of labour in production	$\mu = 0.67$
Share of government spending in output	$g = 0.2$
Share of profit taxes in total taxes	$\varrho = 0.15$
Calvo price setting	$\kappa = 0.75$
TFP shocks	$\eta_u = 0.95$, $\sigma_u = 0.006$
News shocks	$\eta_v = 0.9$, $\sigma_v = 0.019$
Labour supply shocks	$\eta_\Delta = 0.9$, $\sigma_\Delta = 0.025$
Taste shocks	$\eta_\Psi = 0.9$, $\sigma_\Psi = 0.01$
Mark-up shocks	$\eta_\upsilon = 0.0$, $\sigma_\upsilon = 0.0015$
Government spending shocks	$\eta_G = 0.9$, $\sigma_G = 0.003$

The TFP and news shocks processes are based on Corsetti *et al* (2010, 2011). The parameters of the other shock processes are approximately based on the estimates of Smets and Wouters (2003, 2005, 2007).

5.2 Benchmark results

Our benchmark case assumes producer currency pricing (PCP). Benchmark results are presented in Table 2. This table shows results for a range of values of the international trade elasticity, θ, from 0.25 to 3.

The first line of this table shows the difference in welfare between optimal policy and a policy of PPI inflation targeting. Welfare is measured in terms of the equivalent percentage change in steady state consumption. It is apparent from the table that the welfare gain from optimal policy relative to inflation targeting is very small for all values of θ. The welfare gain tends to be slightly higher for higher values of θ but it is never

Table 2: Results for the Benchmark Case

Trade elasticity, θ		0.25	0.5	0.75	1.5	3
Welfare difference		0.0025	0.0030	0.0033	0.0039	0.0043
Policy rule	δ_Y	0.129	0.129	0.129	0.129	0.129
	δ_τ	-0.022	-0.076	-0.276	-0.006	-0.003
	$\delta_{\mathcal{D}}$	0.590	-0.635	-0.704	-0.978	-0.534
	$\delta_{\mathcal{L}}$	0	0	0	0	0
	δ_π	1.002	0.996	0.998	0.998	0.998
Standard Deviations						
PPI Inflation	(optimal)	0.0066	0.0084	0.011	0.0072	0.0042
Output gap	(optimal)	0.021	0.062	0.082	0.096	0.090
	(inf tar)	0.030	0.096	0.14	0.20	0.25
RER gap	(optimal)	2.7	1.8	1.3	0.6	0.3
	(inf tar)	3.8	2.7	2.1	1.3	0.7
Trade bal gap	(optimal)	0.24	0.030	0.16	0.28	0.30
	(inf tar)	0.35	0.048	0.27	0.59	0.83

larger than 0.005%. The fact that the welfare gain rises with θ contrasts with the results in Corsetti *et al* (2010, 2011) who show that (for a single bond economy) financial market incompleteness implies a larger welfare gain when θ has a low value.

Table 2 also reports the coefficients of the optimal policy rule. Despite the small welfare gain generated by optimal policy, it is clear from the table that optimal policy implies quite a significant departure from inflation targeting in terms of the policy rule coefficients. Recall that PPI inflation targeting implies $\delta_\pi = 1$, $\delta_Y = \delta_\tau = \delta_{\mathcal{D}} = \delta_{\mathcal{L}} = 0$. Table 2 shows that optimal policy implies relatively large values (in absolute terms) for the coefficient on the risk sharing gap, $\delta_{\mathcal{D}}$, so optimal policy requires a strong response to the departures from full risk sharing that arise because of the incomplete market structure.

The lower half of Table 2 shows the implications of optimal policy and inflation targeting for the volatility of a number of variables. (The figures shown here are standard deviations in percentage terms.) It is apparent from this table that optimal policy implies quite a small standard deviation for PPI inflation. Inflation volatility is at its highest for the case where $\theta = 0.75$, where the standard deviation of inflation is just 0.011%. Optimal policy therefore implies quite a small deviation from inflation targeting in terms of the volatility of inflation. But the other figures in Table 2 show that optimal policy has quite a large impact on the volatility of a number of other important variables. In particular, the output gap (i.e. the difference between actual and first-best output), the real exchange rate gap (i.e. the difference between the actual and first-best real exchange rate) and the trade balance gap (i.e. the difference between the actual and first-best trade balance) are all quite significantly less volatile under optimal policy than they are under a policy of inflation targeting. The impact of optimal policy on the real exchange rate gap and trade balance gap is of particular interest because this shows that optimal policy tends to deviate from strict inflation targeting in order to off-set external misalignments, just as demonstrated by Corsetti *et al* (2010, 2011) in the context of autarky or single bond economies.

Our benchmark case is one where there is trade in both equities and bonds. It is useful to compare welfare results yielded by this case with those yielded by other financial market structures. Table 3 shows welfare results for our model with three alternative financial market structures: autarky, a single non-contingent bond and complete markets.

It is clear that the welfare difference between optimal policy and inflation targeting is much smaller in the case of complete markets. It is also apparent that, for values of θ

Table 3: Welfare and alternative financial market structures (PCP)

Trade elasticity, θ	0.25	0.5	0.75	1.5	3
Bonds and equities	0.0025	0.0030	0.0033	0.0039	0.0043
Single bond	0.0039	0.32	7.2×10^{-6}	2.9×10^{-5}	7.6×10^{-5}
Complete markets	5.7×10^{-6}	6.2×10^{-6}	6.6×10^{-6}	7.5×10^{-6}	8.4×10^{-6}
Autarky	8.9×10^{-4}	0.10	4.0×10^{-5}	1.1×10^{-5}	7.4×10^{-6}

close to 0.5, the welfare gain from optimal policy is much higher in the autarky and single-bond cases. For instance, in the single bond case at $\theta = 0.5$, the welfare difference rises to 0.32% of steady state consumption. These last results thus replicate (in qualitative terms) the Corsetti *et al* (2010, 2011) results which emphasise that the welfare gain from optimal policy can be quite significant for low values of θ. Notice, however, that, in contrast to the arguments of Corsetti *et al* (2010, 2011), the impact of θ on the welfare gain appears to be non-monotonic. So, for very low values of θ (i.e. $\theta = 0.25$) the welfare gain of optimal policy is very small, even in the autarky and single bond cases.

5.3 Local currency pricing

Corsetti *et al* (2010, 2011) argue that financial market incompleteness is likely to be particularly important in the case of local currency pricing (LCP). Table 4 therefore reports results for this case where we now compare optimal policy to CPI inflation targeting.

The results reported in Table 4 for the LCP case appear to be very similar to those shown in Table 2 for the PCP case. As in the PCP case the welfare gains for optimal policy relative to inflation targeting are small. In no case is the welfare gain more than 0.005% of steady state consumption. It therefore appears that, in contrast to the results reported by Corsetti *et al* (2010, 2011), there is no significant difference between the LCP and PCP cases in terms of welfare.

Despite the small welfare gain from optimal policy, Table 4 shows that, as with the PCP case, optimal policy does imply quite significant departures from inflation targeting in terms of the coefficients of the policy rule. Recall that CPI inflation targeting implies $\delta_\pi = \delta_Y = \delta_\tau = \delta_\mathcal{D} = \delta_\mathcal{L} = 0$. It is apparent from Table 4 that optimal policy requires quite significant policy responses to departures from risk sharing (as indicated by the

Table 4: Local Currency Pricing

Trade elasticity, θ		0.25	0.5	0.75	1.5	3
Welfare difference		0.0027	0.0030	0.0032	0.0034	0.0037
Policy rule	δ_Y	0.123	2.058	0.186	0.136	0.133
	δ_τ	-1.190	-0.198	-0.312	-0.294	-0.202
	$\delta_\mathcal{D}$	0.252	-1.862	-2.170	-1.039	-1.600
	$\delta_\mathcal{L}$	2.364	0.393	0.528	0.444	0.263
	δ_π	0.302	0.334	0.353	0.330	0.336
Standard Deviations						
CPI Inflation	(optimal)	0.0054	0.0048	0.0043	0.0029	0.0020
Output gap	(optimal)	0.0039	0.11	0.15	0.21	0.24
	(inf tar)	0.0078	0.15	0.20	0.28	0.33
RER gap	(optimal)	2.8	2.0	1.7	1.4	1.4
	(inf tar)	3.7	2.7	2.2	1.6	1.4
Trade bal gap	(optimal)	0.72	0.42	0.29	0.31	0.46
	(inf tar)	0.72	0.39	0.33	0.56	0.85

Table 5: Welfare and alternative financial market structures (LCP)

Trade elasticity, θ	0.25	0.5	0.75	1.5	3
Bonds and equities	0.0027	0.0030	0.0032	0.0034	0.0037
Single bond	0.0062	0.35	6.8×10^{-4}	2.3×10^{-4}	1.0×10^{-4}
Complete markets	1.2×10^{-3}	9.2×10^{-4}	7.2×10^{-4}	3.9×10^{-4}	1.5×10^{-4}
Autarky	–	–	1.0×10^{-3}	9.7×10^{-5}	1.4×10^{-4}

non-zero value for $\delta_{\mathcal{D}}$), the terms of trade gap (as indicated by the non-zero value for $\delta_{\mathcal{T}}$) and departures from the law of one price (as indicated by the non-zero value for $\delta_{\mathcal{L}}$).

The lower half of Table 4 shows that, as with the PCP case, optimal policy appears to deliver quite significant stabilisation of the real exchange rate and trade balance relative to their first best values.

Table 5 shows a comparison between the bonds and equity economy and the autarky, single bond and complete markets cases, where each of these cases is now evaluated with local currency pricing. This table shows a similar pattern to the same comparison shown for the PCP case in Table 3. Table 5 shows a significant welfare gain from optimal policy for values of θ close to 0.5 in the single bond case. This corresponds to the Corsetti *et al* (2010, 2011) result (but, as in the PCP case, the welfare gain appears to decline for very low values of θ).

Notice that the welfare gain in the single bond economy for $\theta = 0.5$ is similar in magnitude to the welfare gain in the equivalent PCP case, so contrary to the argument in Corsetti *et al* (2010, 2011), we do not find any significant role for LCP in generating especially large welfare gains even for the single bond case analysed by Corsetti *et al* (2011).

5.4 Parameter variations

We now briefly consider the effects of varying a number of key parameters away from their benchmark values. Table 6 summarises the effects of varying the share of home and foreign goods in the consumption basket, γ, the degree of risk aversion, ρ, and the elasticity of labour supply, $1/\phi$. For each parameter variation we show a range of values for θ and for each parameter combination we show the welfare difference between optimal policy and

Table 6: Parameter variations

	θ	Welfare difference[1] 0.5	1.5	6	St Dev RER gap[2] 0.5	1.5	6
γ	0.6	0.0040	0.0046	0.0050	0.28	0.24	0.22
	0.7	0.0037	0.0044	0.0049	0.41	0.28	0.22
	0.8	0.0033	0.0042	0.0048	0.55	0.37	0.24
	0.9	0.0029	0.0038	0.0046	0.68	0.53	0.30
ρ	0.5	0.0037	0.0054	0.0082	0.85	0.75	0.56
	1	0.0033	0.0045	0.0059	0.78	0.64	0.42
	2	0.0030	0.0039	0.0047	0.65	0.48	0.27
	5	0.0033	0.0041	0.0046	0.40	0.26	0.13
ϕ	0.5	0.0066	0.0099	0.0136	0.61	0.50	0.32
	2	0.0030	0.0039	0.0047	0.65	0.48	0.27
	5	0.0017	0.0021	0.0024	0.68	0.48	0.26
	9	0.0013	0.0016	0.0017	0.70	0.48	0.25

1. Welfare difference between optimal and inflation targeting

2. StDev(optimal policy)/StDev(inflation targeting)

inflation targeting and also the ratio of the standard deviation of the real exchange rate gap for optimal policy relative to the standard deviation for inflation targeting. If this ratio is less than unity it implies that optimal policy stabilises the real exchange rate gap relative to inflation targeting, the more so the smaller is this ratio.

The first set of results in Table 6 shows the effects of varying the share of home and foreign goods in the consumption basket, γ. This can be thought of as a measure of openness, where a value of γ close to 0.5 implies a more open economy and a value of γ close to unity implies less open economy. The results in Table 6 show that the welfare gains from optimal policy are marginally larger for more open economies (i.e. for values of γ close to 0.5). It also appears that the stabilising effect of optimal policy on the real exchange rate gap is also more significant for more open economies.

The second set of results in Table 6 show the effects of varying the degree of risk aversion, ρ. The results show that the welfare gains for optimal policy appear to increase as risk aversion is reduced. On the other hand the stabilising effect on the real exchange rate gap increase as risk aversion increases.

The third set of results in Table 6 show the effects of varying the elasticity of labour supply, $1/\phi$. The results show that the welfare gains from optimal policy are higher when labour supply is more elastic. The labour supply elasticity has only a minor effect on the stabilising effect of optimal policy on the real exchange rate gap.

The overall message from Table 6 is that varying the three parameters shown has a relatively small effect on the welfare gain from optimal policy.

Table 7 shows the effect of varying the parameter η in the endogenous discount factor (for the case where $\theta = 1.5$). This table shows that, in contrast to effects of the parameters shown in Table 6, varying η has a potentially very significant effect on the size of welfare gains. A very small value of η implies that the discount factor adjusts very gradually to changes in aggregate consumption. This in turn implies that transitory shocks can have very long lasting effects on net foreign assets. In the absence of any deliberate policy response, this tends to raise the variance of consumption and work effort and thus has potentially strong negative effects on welfare. Optimal policy tends to counter these effects by placing a stronger emphasis on the risk sharing gap in the policy rule (i.e. the parameter $\delta_{\mathcal{D}}$) for low values of η (as can be seen in Table 7). A policy of inflation targeting on the other hand ignores the implication of volatile net foreign assets for welfare and thus the welfare performance of inflation targeting is significantly lower than optimal policy when η is small. It therefore follows that, as shown in Table 7, the welfare gain from optimal policy is larger for small values of η. Note however that, for small values of η, the variances of consumption and work effort are unrealistically large, so the large welfare gains from optimisation are not empirically plausible.

Our final robustness check focuses on exogenous shocks. In our benchmark model there are 6 sources of shocks. In unreported experiments we investigate the effect of excluding each of these shocks in turn. It appears from these experiments that taste shocks have a particularly important role in generating the welfare and stabilising effects of optimal policy. Excluding each of the other shocks has only a small effect on welfare and stabilisation properties of optimal policy compared to the benchmark case. But excluding taste shocks significantly reduces the welfare gain from optimisation and also almost eliminates the stabilising effect of optimal policy on the real exchange rate gap.

Table 7: Alternative values for η

η		0.0001	0.0005	0.001	0.005	0.01
Welfare difference		0.15	0.031	0.016	0.0039	0.0023
Policy rule	δ_Y	0.129	0.129	0.129	0.129	0.129
	δ_τ	0.004	0.004	0.002	-0.006	-0.012
	$\delta_{\mathcal{D}}$	-19.3	-5.48	-3.23	-0.98	-0.594
	$\delta_{\mathcal{L}}$	0	0	0	0	0
	δ_π	0.999	0.999	0.999	0.998	0.997
Standard Deviations						
PPI Inflation	(optimal)	0.0048	0.0052	0.0055	0.0072	0.0084
Output gap	(optimal)	0.023	0.036	0.047	0.096	0.13
	(inf tar)	1.1	0.49	0.35	0.20	0.19
RER gap	(optimal)	0.0097	0.21	0.29	0.63	0.88
	(inf tar)	7.2	3.2	2.3	1.3	1.3
Trade bal gap	(optimal)	0.0042	0.0092	0.13	0.28	0.40
	(inf tar)	3.2	1.5	1.0	0.59	0.57

6 Model Extensions

In this section we briefly consider an extended version of the model which includes endogenous real capital and partial backwards indexation of prices. These two modifications bring the model closer to a fully dynamic model that is comparable to the structures developed in Christiano *et al* (2005) and Smets and Wouters (2003).

Variable real capital, and shocks that affect investment create a strong role for current account dynamics and thus create potentially important trade-offs between internal and external policy objectives.

We introduce partial backward indexation in price setting by assuming that those nominal prices which are not reset in any given period are up-dated with degree of indexation given by ω (where $0 \leq \omega \leq 1$). So, for instance, if firm z in the home final goods sector has price $p_{t-1}(z)$ in period $t-1$ and that firm does not have the opportunity to re-optimise its price in period t then its price in period t will be given by

$$p_t(z) = p_{t-1}(z) \left(\frac{p_{t-1}}{p_{t-2}}\right)^{\omega}$$

where p_{t-1}/p_{t-2} is the rate of inflation of the aggregate price of home final goods between period $t-2$ and $t-1$. Based on Smets and Wouters (2003) we set $\omega = 0.5$.

The introduction of variable real capital implies that the capital stock accumulates as follows

$$K_{t+1} = I_t + (1 - \varsigma)K_t$$

where $0 \leq \varsigma \leq 1$ is the rate of depreciation and I_t is investment in new capital goods.

Capital is subject to adjustment costs given by $\varphi(I_t)$ where we assume $\varphi(\bar{I}) = \varphi'(\bar{I}) = 0$, $\varphi''(\bar{I}) > 0$. Capital has the same composition as consumption (see equation (3)) so the price of investment goods is given by (4).

The representative intermediate goods firm now chooses L_t, I_t and K_t to maximize the real discounted value of dividends, given by

$$E_t \sum_{i=0}^{\infty} \Omega_{t+i} \Upsilon_{t+i} \left[\frac{q_{t+i}}{P_{t+i}} Y_{t+i} - \frac{w_{t+i}}{P_{t+i}} L_{t+i} - I_{t+i} - \varphi(I_{t+i})\right]$$

subject to the production function and capital accumulation equations. We also introduce a new shock, Υ_t, which represents shocks to the cost of funds to firms. Smets and Wouters (2003) refer to this as a risk premium shock and suggest that it captures the effects of variations in the external finance premium. We assume that $\Upsilon_t = \exp(\hat{\Upsilon}_t)$ and

$\hat{\Upsilon}_t = \eta_\Upsilon \hat{\Upsilon}_{t-1} + \varepsilon_{\Upsilon,t}$, $0 \leq \eta_\Upsilon < 1$ and $\varepsilon_{\Upsilon,t}$ is a zero-mean normally distributed i.i.d. shock with $Var[\varepsilon_\Upsilon] = \sigma^2_\Upsilon$.

Total private sector expenditure is now given by

$$D_t = C_t + I_t + \varphi(I_t) \tag{11}$$

so home demand for home final goods is

$$D_{H,t} = \gamma \left(\frac{P_{H,H,t}}{P_t} \right)^{-\theta} D_t \tag{12}$$

Total after-tax dividends aggregated across all intermediate and final goods firms are given by

$$\Pi_t = \frac{P_{Y,t}}{P_t} Y_t - \frac{w_t}{P_t} L_t - I_t - \varphi(I_t) - T_{C,t}$$

The rate of depreciation of real capital, ς, is set at 0.025 (implying an annual rate of depreciation of 10%) and the capital adjustment cost function is parameterized to yield a variance of total investment which is approximately 3 times the variance of GDP (which is consistent with the data for most developed economies). The parameter values for the risk premium shock are based on Smets and Wouters (2003), so we set $\eta_\Upsilon = 0$ and $\sigma_\Upsilon = 0.006$.

The main results for the extended model are reported in Table 8.

It is apparent that the general conclusions from the benchmark case carry over to the extended model, i.e. the welfare gain from optimisation is quite small while optimal policy implies lower volatility of the real exchange rate gap and the trade balance gap than implied by inflation targeting.

7 Conclusions

Recent literature on monetary policy in open economies (Corsetti *et al*, 2010, 2011) shows that, when international financial trade is absent or restricted to a single non-contingent bond, there are significant internal and external trade-offs that prevent optimal policy from simultaneously closing all welfare gaps. In this case optimal monetary policy deviates from inflation targeting in order to offset real exchange rate misalignments. These simple models of financial market incompleteness provide important theoretical insights but they are obviously not good representations of modern financial markets. This paper therefore analyses a more general model of incomplete markets, where there is international trade in both bonds and equities. The analysis shows that, as in the

Table 8: Extended model

Trade elasticity, θ		0.25	0.5	0.75	1.5	3
Welfare difference		0.0022	0.0023	0.0022	0.0030	0.0034
Policy rule	δ_Y	0.395	0.711	4.285	0.338	0.249
	δ_τ	-0.005	-0.020	-0.269	-0.010	-0.010
	$\delta_{\mathcal{D}}$	1.550	1.891	3.235	-2.026	-0.600
	$\delta_{\mathcal{L}}$	0	0	0	0	0
	δ_π	1.025	1.015	0.960	1.030	1.047
Standard Deviations						
PPI Inflation	(optimal)	0.32	0.28	0.25	0.20	0.15
Output gap	(optimal)	0.0076	0.0096	0.13	0.15	0.14
	(inf tar)	0.16	0.18	0.21	0.26	0.29
RER gap	(optimal)	3.3	2.3	1.7	0.89	0.55
	(inf tar)	3.8	2.7	2.1	1.2	0.70
Trade bal gap	(optimal)	0.21	0.0050	0.17	0.33	0.52
	(inf tar)	0.24	0.0073	0.21	0.42	0.61

recent literature, optimal monetary policy deviates from inflation targeting in order to offset exchange rate misalignments, but the welfare difference between optimal policy and inflation targeting is quantitatively smaller than found in the simpler models of financial incompleteness analysed in Corsetti *et al* (2010, 2011). It is found, however, that optimal policy does imply quantitatively significant stabilisation of the real exchange rate gap and the trade balance gap compared to inflation targeting.

This paper focuses on a model of imperfect financial markets where the imperfection simply takes the form of a restricted set of financial instruments (i.e. bonds and equities) which is insufficient to provide full international risk sharing. Devereux and Sutherland (2011b) show that the presence of collateral constraints can significantly alter the international transmission of shocks, especially in the case when there is trade in bonds and equity. In a companion paper (Senay and Sutherland, 2016) we analyse optimal monetary policy in a version of the above model which has been extended to incorporate the form of collateral constraints introduced in Devereux and Sutherland (2011b).

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